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Report of Proceedings

Eastern Experiment Station Collaborators' Conference on FOOD PROCESSING TECHNIQUES

October 22 & 23, 1963

EASTERN UTILIZATION RESEARCH & DEVELOPMENT DIVISION
AGRICULTURAL RESEARCH SERVICE
U.S. DEPARTMENT OF AGRICULTURE
PHILADELPHIA, PENNA. 19118

Report of Proceedings

Eastern Experiment Station

Collaborators' Conference on

FOOD PROCESSING TECHNIQUES

October 22 and 23, 1963

Held at the

Eastern Utilization Research and Development Division

Agricultural Research Service

U. S. Department of Agriculture

Philadelphia, Pennsylvania 19118

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This conference was attended by representatives of the State Agricultural Experiment Stations, universities, the Quartermaster Research and Engineering Center, and the United States Department of Agriculture. (Names and addresses of the conferees appear at the back of this publication.)

This report summarizes the discussions of the conference speakers. Further details on any particular topic may be obtained by communicating directly with the speakers.

EASTERN EXPERIMENT STATION COLLABORATORS' CONFERENCE

ON FOOD PROCESSING TECHNIQUES

October 22 and 23, 1963

Program and Contents

71370

INTRODUCTORY REMARKS

by

P. A. Wells
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Philadelphia, Pennsylvania

Dr. Wells welcomed the delegates to the conference. He pointed out that this collaborators' conference represented our 18th since they were initiated here in 1947. The system of collaborator appointments was originated by Dr. Orville May, then Chief of the Bureau of Agricultural and Industrial Chemistry, and Dr. E. C. Auchter, then Administrator of the Agricultural Research Administration (now called Agricultural Research Service).

For the first two years the collaborators made individual visits of two or three days to the Division at any time during the year. Since that time we have held annual collaborators' conferences devoted to research on a specific agricultural commodity or in a specific area of research such as the present one on Food Processing. Several of these conferences (Tobacco, Potatoes, and Milk Concentrates) have been continued by their respective industries and have been meeting annually at various locations.

A report of the present conference will be prepared, consisting of summaries of the papers presented. Single copies will be mailed to each of those attending, and additional copies will be furnished on request.

FOAM SPRAY DRYING - A NEW TECHNIQUE FOR DEHYDRATED PRODUCT IMPROVEMENT

by

M. J. Pallansch
Eastern Utilization Research and Development Division
Washington, D. C.

A very recent review of the progress made in the field of milk drying during the past ten years clearly demonstrates that much effort continues to be expended to obtain the ideal solution for a very difficult problem. That problem has been and remains the production of stable, easily dispersible powders which reconstitute to a material having the flavor of fresh milk.

Much of the reported work concerns methods for producing improved nonfat products by "instantizing" operations. The success of this research has lead to a growing acceptance of nonfat powders in the home consumer market.

Work carried on in this Division has been aimed at the development of improved whole milk powders. This work received much of its initial impetus from the investigations of Sinnamon and his associates of this Division. They demonstrated that a whole milk powder of excellent solubility and flavor could be produced by drying a nitrogen gas expanded foam of concentrated whole milk at low temperatures under a high vacuum. This team, at present, is carrying out research on the continuous production of whole milk powders of this type.

In our Dairy Products Laboratory in Washington, research teams have been engaged in extending the storage life of vacuum foam dried products and determining the physical factors responsible for their excellent solubility and flavor.

Research results now in the process of being published demonstrated that many of the desirable features of this new type of dry milk powder arose from its foam structure. To further test this idea and possibly produce an easily dispersible spray-dried whole milk powder, the effects of injecting a relatively insoluble gas into the feed of a conventional spray dryer were studied. This was found to produce powders consisting primarily of spherical, fused particles of dried whole milk foam. They had excellent initial flavor and improved dispersibility, and in addition, dryer performance was improved.

This presentation, therefore, will concern a brief description of the method developed in our Dairy Products Laboratory for the production of whole milk foams by use of conventional spray drying. Some physical characteristics of the spray-dried foam will be described. A more formal and complete treatment of this subject has recently been published in the Journal of Dairy Science (1962). The work described was carried out with milk standardized to 3.3% fat, heated to 165° F for 15 seconds, homogenized at 2,500 pounds and concentrated to 50% solids. The concentrate was dried in a 9 foot Swensen spray dryer equipped with a standard pressure nozzle. A short distance from the pump, a stainless steel T was inserted in the line to the nozzle to permit the injection of pressurized nitrogen into the line. The gas was obtained from high pressure cylinders and controlled by use of a reducing valve, flow meter, and needle valve placed in the injection line.

Experimental powders were made using different nitrogen to concentrate ratios in the feed and by spraying these mixtures through nozzles with orifice sizes ranging from 0.040 to 0.050 inch in diameter. In general, it was found that the injection of pressurized nitrogen into the pressure side of the feed line just prior to atomization produces spray-dried powders having increased bulk and improved dispersibility.

As the amount of nitrogen in the feed is increased, the amount of concentrate dried decreases along with the bulk density and moisture contents of the resultant powder. It was also found that increasing amounts of nitrogen in the feed increases the dispersibility, free fat, and powder particle diameters. Nitrogen injection also increased the "streamline" surface areas of the particles as well as their absolute surface areas. These surface increases were accompanied by decreases in the apparent densities of the powder particles.

As the input of concentrate to the dryer is increased by the use of larger orifices, the powder produced without gas injection is of such high moisture content that it is commercially unusable. This loss in ability to adequately dry high solids input is less marked when nitrogen gas is incorporated into the concentrate prior to atomization. In fact, the output of 3% moisture containing whole powder has been increased approximately 20% by the use of this gas injection technique.

The appeal of this method lies in the fact that it not only allows the production of an improved whole milk powder, but it also lends itself to further experimentation with commercial scale equipment without the expenditure of large sums of money for dryer modification.

Experience in our laboratories has already demonstrated that this method can be used to dry cottage cheese whey and sodium caseinate. Since the dry particles contain trapped nitrogen, some foam is formed in the reconstituted product. In cases where this is not objectionable or restrictive, the described method of spray drying warrants additional investigation.

At the present time, the flavor stability of spray-dried whole milk foam is undergoing extensive study. From results obtained during studies of vacuum dried foams, it seems highly probable that the production and packaging conditions necessary for at least 6 months storage at ordinary room temperature will be defined in the near future. Whether or not these conditions can be carried out under commercial conditions will require additional research.

VACUUM FOAM DRYING

by
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Philadelphia, Pennsylvania

In this day of convenience foods rapid reconstitution of a dehydrated product is essential. This attribute is enhanced by a porous structure which affords a large surface area and ready access to the reconstituting medium. Freeze dried products, although not foams, illustrate this principle, as do explosive puffed fruit and vegetable pieces.

Liquids and slurries may be foamed and spray dried, as with coffee extract and more recently, milk. They may be dried under atmospheric pressure as in foam-mat drying or they may be dried under vacuum. A porous structure resulting from the vacuum drying of a liquid or slurry may be obtained in two distinct ways. In one, boiling is caused by maintaining the drying chamber at a pressure below the vapor pressure of the material fed to it. The evolved water vapor creates a course, bubble structure resembling a foam, which becomes rigid as drying proceeds. This is done commercially in the case of citrus juice concentrates and more recently concentrated coffee and tea extracts. Such a process is generally termed "puff drying."

The other approach is to form a fine grained foam by gas injection before introducing it to the drier chamber and then drying so as to preserve the foam or at least to retain its essential attributes. This is the type of vacuum foam drying under discussion--specifically as we have applied it to concentrated whole milk. At the moment I can think of no food product made commercially by this method.

A continuing surplus of dairy products, especially butterfat, has stimulated research in the Department of Agriculture to increase utilization. One partial solution would be for people to drink more whole milk. But milk is expensive on the doorstep and awkward to carry home from the store. A really good dry whole milk that would disperse easily, taste like the fresh product and cost less than the fresh product would undoubtedly stimulate consumption.

Dry skim milk is now widely used as a beverage in the home; in fact, per capita consumption has increased more than 4-fold in the past 20 years, whereas, per capita use of dry whole milk has not changed during the same period. Why? Because the butterfat in whole milk militates against the use of the spray drying and instantizing techniques which have proved so successful with skim milk. Whole milk is spray dried to the extent of some 100 million pounds annually but its flavor and poor dispersibility discourage its use as a domestic beverage.

The poor flavor of commercial dry whole milk probably arises from three causes; First - Forewarming. Forewarming is heating the milk for 10 minutes or so at 185° F. in order to develop natural antioxidants to afford protection during spray drying and storage. Concomitants of forewarming unfortunately are a cooked taste and an impaired dispersibility as a consequence of denaturation of some of the lactoglobulins. Therefore, to improve flavor and dispersibility forewarming should be eliminated.

Second - Oxidation. Oxidation occurs from spray drying in air which is tenaciously retained inside the dried particles even after prolonged evacuation prior to nitrogen packaging. Thus one should exclude air as far as possible in all steps of the process including drying.

Third - Heat Damage. Some heat damage is inevitable in the course of drying at atmospheric pressure hence drying should be done at reduced temperatures, e.g., under vacuum.

The desirability of these changes was obvious, but to accomplish them at a reasonable cost and to obtain a product of easy dispersibility and fresh milk flavor posed difficult engineering, chemical and technological problems.

A batch process was described that has yielded a product of excellent cold water dispersibility and initial flavor closely comparable to fresh milk and far superior to commercially dried whole milk. How this process was translated to continuous operation using a high vacuum drier manufactured by the Chemetron Corporation of Louisville, Kentucky was described. It proved necessary to make some changes in drier design. These entailed introducing more heating elements to obtain very rapid evaporation in the early drying stages, reversing the belt direction, and extruding the foamed concentrate from a nozzle located above the belt instead of applying the material in the conventional way to the bottom of the belt using a dip roller.

Results from the continuous drier were fully equal to those obtained by batch operation. It was estimated that it should ultimately be possible to produce dried whole milk by this process as a profitable enterprise. The excellent dispersibility of the product is retained throughout a year's storage at room temperature. The flavor is retained for fully 9 months if the product is stored under ordinary refrigeration. More research is required to achieve sufficient shelf-life at room temperature. The product must of course be packed in nitrogen and the contents of the package must be reconstituted immediately after once opening.

HIGH-TEMPERATURE-SHORT-TIME (HTST) PROCESSING

by
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Heat processing, in the face of competition from several other processing methods, each of which has been regarded by many people as holding the key to the future of food preservation, continues to increase its dominance of the field. Increasing interest in high-temperature-short-time processing techniques is partially responsible for the continued high regard for sterilization by heat.

Of the four factors that count heavily in determining the merits of a process, three lend strength to the claims for the accomplishments of HTST processing. These factors are (1) economy of operation, (2) quality of product, and (3) uniformity of product. The fourth factor is sterilization of product, which of course, is done satisfactorily by either HTST or conventional heat processing.

Since 1920, the date of the first HTST patent mentioned in the literature, many patents have appeared covering processes and machinery classified as HTST. These may belong to any one of three basic patterns. The first method consists of violently agitating the canned food while it is being heated and cooled to produce rapid heating and cooling of the product. The second method consists of heating the food either in bulk or in open cans, after which it may or may not be partially cooled, sealing the container at its maximum temperature or at some lower temperature above 212°F. under pressure after having been partially cooled rapidly either by flash treatment or otherwise, holding the sealed container to allow the residual heat in the food to complete the sterilization of the container surfaces and of the food, and completing the cooling as rapidly as possible. This procedure is sometimes called the PFC (pressure filling and closing) method. It is not an aseptic canning method.

The third method is heating the food in bulk, holding at the maximum temperature if necessary to complete the sterilization of the food, cooling rapidly either by flash treatment or otherwise, all under aseptic conditions, and finally putting the sterile cooled food into a sterile container aseptically and sealing the container with a sterile cover. This procedure is called the HCF (heat-cool-fill) method. It is aseptic canning.

Depending upon the viscosity of the product, the dimensions of the container, and the volume of the headspace, the rate of heating of a product increases as the rate of rotation of the container on its main axis increases up to from 100 to 200 r.p.m. Either reciprocating motion or end-over-end rotation is more effective than rotation on the axis.

The major effort to advance high-temperature-short-time sterilization during the period 1926-1941 was conducted by the laboratories of the American Can Company led by Ball. The work included studies in all three types of operation and a wide variety of products was studied including milk concentrate, whole milk, cream style and whole kernel corn, various vegetables and vegetable purees and chop suey.

A unit of PFC type of commercial scale operated experimentally on whole kernel corn in 1935 and on a commercial basis in 1936 and, for 20 years, starting in 1940,

a commercial HCF machine operated commercially on concentrated chocolate milk drink. In the 1940's activity in the field was quickened by the advent of investigators under various sponsorships, including two or three universities and various container manufacturers. The most prominent development during this period was that of the Dole Aseptic Canning System on HCF type system for liquids by the Dole Engineering Company. There are now 57 installations of this system, of which seven are in foreign countries. Approximately half of the units are reported to be operated on a commercial scale, most of them on concentrated dairy products.

Two difficulties have caused an inordinately low rate of acceptance of HTST by the canning industry. The first is physical instability of HTST processed milk concentrates, which has been recognized as a problem since 1932 and which persists today as only a partially solved problem. Various influencing factors suggest strongly that the instability (gelation) is triggered by enzymes. Assuming this to be the case, the industry appears to be faced with the problem of developing a complex time-temperature cycle to accomplish preservation of the food. The second major retarding factor is an engineering stalemate, evidenced as failure to design heat exchangers equal to the task of sterilizing the foods in bulk at a satisfactory rate for a satisfactory length of time.

The major difficulty is experienced with foods of particulate nature. During the last five years, William M. Martin, the inventor of the Dole Aseptic Canning System, has developed a heat exchanger for products consisting of solid pieces in heavy sauce in which the product is heated in direct contact with super-heated steam. This device appears to have promise.

While the advance of HTST processing has been slow, nevertheless, both the number of research and development projects on equipment and methods for utilizing HTST processes and the number of commercial applications of the principle of HTST have increased manyfold in each decade since 1920. Today, it is safe to say that the laboratory of every large canning organization is either carrying on HTST research and development work or is keeping as closely as possible in touch with developments by others. The indication is that every baby food packer and every large meat packer is either associated with some active HTST research or is contemplating such research.

RADIATION PRESERVATION OF FOODS

by
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Except for canning, developed approximately 150 years ago, radiation processing is the only completely new method of preserving foods developed since the dawn of history. Although canning has been successfully applied to many types of foods, a number of food types cannot be exposed to the extreme temperatures and pressures attendant to thermal processing without suffering serious quality and nutritional losses.

The ability of ionizing radiations to destroy insects and bacteria offered new promise for sterilized foods--free from the destructive effects of thermal processing. But intense interest in commercial application of ionizing radiations for food sterilization did not really develop until after World War II. The primary impetus was provided by the availability of large quantities of radioactive byproducts from the Atomic Energy Commission programs and from industrial development of high energy particle accelerators. An early comprehensive study on radiation processed foods for Armed Forces feedings systems concluded that (1) a ready-to-eat individual combat meal with irradiated food components in flexible packages is urgently needed for best operational support of military units, (2) in 1965-75 irradiated foods would have a distinct advantage over other types of foods in providing suitable combat meals that would be well received by fighting men, (3) the estimated cost of radiation processing would be competitive with the costs of canning, freezing and freeze-dehydration processes and (4) the savings which could result from use of only rations containing irradiated components in a theater of operations is estimated to be about 56 cents per man per day.

Although there are a number of different classes of ionizing radiations, only beta (or electron) and gamma radiations are of interest in food processing. Penetration of electrons in water or material of similar density is approximately one-tenth inch per million electron volts (MEV). Thus, for adequate penetration of material of two-inch thickness an electron beam of 8-10 MEV would be required when irradiation is supplied from opposite sides.

There are advantages and disadvantages for both gamma and beta irradiation. Construction and installation costs of equipment required for production of high energy electrons are high and their use requires highly specialized technical personnel. Maintenance is expensive; furthermore there is an upper limit to the energy which can be employed in processing foods because of measurable induced radioactivity from electron beams with energies in excess of 12 MEV. The principal advantage of electron irradiation is that the machine can be turned on and off at will, simplifying access to it. Additional advantages are its ability to deliver large doses of radiation in seconds and a high efficiency of utilization.

The initial installation cost of an isotope source is based on the cost of the isotope. Once operational and safety procedures have been established little expert attention is required. Disintegration of radio isotopes is a constant process and creates special problems when work must be done in or around the source. Additional problems are encountered in the movement of isotopes from the point of production

to points of use. The constant decay of radio active material necessitates replenishment and relatively frequent intervals for maintenance of proper operating strength.

Although the destructive effect of ionizing radiations on toxicogenic and food spoilage organisms is not clearly defined, it is believed that the lethal properties of irradiation result from both direct hits and indirect hits. The direct hit theory suggests that the nuclear rays or high-speed electrons strike the organisms much as a projectile does and either kill the organisms outright or disrupt their vital functions and cause failure in their reproductive mechanisms.

Indirect action may occur when the highly energetic particle subjects molecules of the organisms near which it passes to an intense transient electrical force, which excites or ionizes the molecules. The ionized or energetic molecules react and produce new substances strange to the chemistry of the cell. The unstable secondary products relay the disturbance in turn to other molecules in the cell.

Unfortunately the nonselective nature of ionizing radiation causes it to have detrimental as well as useful effects. These may appear as changes in flavor, odor, color and texture of the food product and loss of nutritional value. The degree of change depends upon many factors. By careful selection of conditions for radiation, highly acceptable and nutritious food can be preserved without refrigeration for long periods of time and resemble closely fresh food in taste and appearance.

Although the potentialities of irradiation have been amply demonstrated, a wide variety of problems remain to be solved, hence we have divided our program into the following five basic work areas (tasks) each designed to attack one of these problems. (1) Irradiation effects on sensory characteristics of foods. (2) Radiation microbiology. (3) Nuclear effects on foods. (4) Packaging. (5) Wholesomeness program.

Sensory change is one of the most formidable problems. The degree of change is directly related to the dose required for preservation. Insect deinfestation doses (30,000-100,000 rads and _sprout inhibition_ doses (5,000-15,000) have virtually no effect on the quality of products so treated. Pasteurized products which require relatively low doses (100,000-500,000) present only minor problems with respect to palatability.

In microbiological studies, principal effort is directed toward establishing a process which will assure the absence of _Clostridium botulinum_ and its toxin. This organism is one of the most hazardous from a public health standpoint and is also one of the most radiation-resistant spore formers.

The objective of our packaging research program is development of information essential to attainment of lightweight flexible packages capable of withstanding rough handling, possessing long-term protective qualities and not contributing any adverse effects to food.

In our investigations of wholesomeness short-term (two months) animal feeding experiments have been conducted to determine safety from the subacute toxicity standpoint. Based on the results of these tests, over 100 foods were cleared for taste panel evaluation. These studies were subsequently expanded for 21 representative foods covering the spectrum of our major food classes and considered from the standpoint of histopathology, carcinogenicity, toxicity, reproduction and lactation,

growth, longevity, and hematology. No toxicity has been observed that can be attributed to the ingestion of irradiated foods. Reduced growth rate in rats was attributed to thiamine and pyridoxine deficiences and could be corrected by addition of these vitamins to the diet.

The completion of the Army's Radiation Laboratory at Natick during the summer of 1962 provides for the first time the pilot facility for food irradiation with food preparation and radiation processing operations under a single roof. We are optimistic that the program will continue to move rapidly and that by the end of the decade or sooner irradiated products will be in commonplace use.

EXPLOSIVE PUFFING IN DEHYDRATION OF FRUITS AND VEGETABLES

by
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Philadelphia, Pennsylvania

Freeze-drying is still relatively expensive; dehydro-freezing requires frozen storage for the products; atmospheric drying of foamed concentrates and slurries is limited to liquid-form foods; and conventional hot-air drying is limited to small pieces or long drying times, in which case slow reconstitution will result. There has long been a need for a dehydration process operable at moderate cost, applicable to relatively large pieces of fruits or vegetables, and yielding products capable of rapid reconstitution.

Indications are that the newly developed explosive-puffing process developed by the Eastern Utilization Research and Development Division meets the foregoing requirements and is applicable to a wide variety of products. It has been demonstrated successfully in the pilot plant on white potatoes, sweet potatoes, carrots, beets, apples and blueberries.

The process entails conventional drying of vegetable or fruit pieces with hot air to a moisture content in the range of 20 to 40% depending on the particular vegetable or fruit. The drying is then interrupted and the partially dried pieces are superheated under pressure in a closed vessel. When the pressure is suddenly released a small percentage of the contained moisture flashes into vapor, creating a porous structure as it escapes. This porous structure enables a greatly accelerated rate of the final drying operation which is carried out by conventional means. Moreover, the products require only 2 to 6 minutes simmering in water to rehydrate, in contrast to as much as 40 minutes for conventionally dried pieces of the same size. The porosity developed by explosive puffing generally disappears on reconstitution, yielding products with good texture and an appearance close to that of the freshly-cooked product.

As an example, for drying carrots, the steps involved in the process include lye-peeling (1-1/2 - 2 minutes in 20% NaOH), washing, trimming, dicing, sulfiting, blanching (6 minutes in steam), resulfiting to give 500-1000 ppm SO_2 in the final product, initial drying in air at 200°F. to a moisture content of about 35-40%, puffing at about 35 pounds pressure, and final drying to 4% moisture.

Optimum conditions for puffing carrots (moisture content versus pressure) were illustrated and discussed, and a range of moisture content and pressure at which satisfactory product can be made was illustrated. It was shown by a series of curves of drying time versus residual moisture that the moisture content of carrot pieces during puffing has a profound effect on the final drying rate. Pieces puffed at 38% moisture dried to a 4% moisture level more quickly than pieces puffed at higher moistures, probably because the latter are not rigid and collapse to some extent after puffing.

Puffing conditions for other commodities also were described. The use of explosion puffed apple pieces as snacks, in cereals and in pies was discussed and the use of blueberries in muffins was described and illustrated.

Publications on the process are available here as follows:

"Quick-Cooking Dehydrated Vegetable Pieces. I. Properties of Potato and Carrot Products"

"Quick-Cooking Dehydrated Vegetables. Diced Carrots and Beets"

"Explosive Puffing"

"Quick-Cooking Dehydrated Sweet Potatoes"

FOAM-MAT DRYING OF LIQUID-FORM FOODS

by
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Western Utilization Research and Development Division
Albany, California

Foam-mat drying, an entirely new and inexpensive method of food preservation, was discovered by our Eastern Division Laboratory at the Western Utilization Research and Development Division approximately three years ago. We have since developed this method into an automated process on a commercial scale. A number of new food products has resulted from its use, including foam-mat dried tomato and orange. Because of their natural flavor, color, and nutritional content, and their convenience in use, many of these products are already increasing the utilization of farm products through new dry domestic consumer products and through export to countries having no frozen food distribution chain. In addition, some uses of foam-mat products depend on those wartime virtues, reduced bulk and weight. The peacetime counterpart, reduced packaging costs, also plays a role in justifying the process.

Foam-mat drying is a way of dehydrating thin layers of stabilized foam with warm air. The foam structure helps the water get to a free surface where it can evaporate rapidly without forming a skin. The same property helps in the reconstitution of the dried product by allowing the solids to be wet quickly without forming a gum. This last is true because the foam structure is small compared to the size of the particles into which the dry mats have been crumbled.

We have designed equipment to carry out foam-mat drying. Several commercial units have been built and sold which are direct scale-ups of our unit. The process involves metering together the food, the stabilizer (where used), and gas. These flow through a mixer such that a fine-bodied, rather heavy foam stream is formed. This stream is extruded through a slot onto a perforated metal tray. The loaded tray passes over an air blast which pierces the foam lying above each perforation in the tray. Because of its stiffness the foam is not spattered completely off the tray, and the hole stays open. The trays are stacked one above another in the warm air stream which flows through the perforations. At intervals, a new tray is inserted at the bottom and a dry one is removed at the top. The produce is scraped off and the tray is returned to the cycle. Dry density and frothiness of the reconstituted product can be improved by crushing the dry product between warm rolls before packaging.

Foam-mat dryers are being fabricated by three manufacturers: Food Machinery Corp., American Machine and Foundry, and Chemet Engineers. Foam-mat drying is being used commercially for preparing tomato powder for use in dry soup mixes, and for drying pizza and spaghetti mixes. Lemon powder for lemonade and lime powder for limeade is being made for export. Orange and grapefruit powders are now being consumer tested as juices. Pilot quantities of pineapple, Concord grape, and banana powders have been made. Instant Kona coffee and tea are being compared industrially with the same products dried in other ways. Instant cereal products and molasses powders have been made by foam-mat drying in commercial laboratories.

While new possibilities for useful products by this method are still appearing, the best successes have been in citrus juices and tomato. These commodities now

benefit greatly from their sale as concentrates. Foam-mat drying the remaining moisture further increases product utility while still requiring the use of the existing concentration plants.

PRINCIPLES OF FREEZE DRYING

by
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Oregon State University, Corvallis, Oregon

The commercial freeze-drying of foods, begun on a small scale in Europe in 1946, has received little popular attention in this country until the last two or three years. However, it now appears to give promise of becoming one of the major methods of food preservation.

Freeze-drying consists of freezing the product and then subliming or evaporating the water present in crystalline form. This process is also referred to as lyophilizing. Drying requires that energy be transferred into the product and that the water vapor be transferred through and away from it.

Water vapor may be removed from the frozen food by blowing subfreezing dry air across it. This process, however, requires such large quantities of air movement that it would be impractical except, perhaps, in a few special cases.

Another method of removing water vapor is by means of desiccants. This, however, does not appear practical when we consider the mass of desiccant materials required and the energy and equipment necessary to dry them out.

Another approach to the problem of moisture removal is to reduce the pressure in a sealed drying chamber. If the pressure within the chamber is less than the vapor pressure of the ice, water molecules will evaporate rapidly from the frozen product until the area within the chamber becomes saturated with water vapor. Use of a vacuum pump will remove most of the oxygen and nitrogen molecules until the pressure inside will be due mainly to the water vapor molecules.

Providing sufficient pumping capacity to remove all the water in vapor form appears impractical when we consider the displacement capacity required at pressures of 50 to 200 microns of mercury used for fruits and 700 to 1000 microns used for meats and vegetables. These low pressures are necessary to hold the products below their eutectic temperatures. Steam injection, however, can be used, and is practiced in Europe.

A better approach is to condense the vapor either within the chamber or in a separate chamber. Heat energy, applied to the frozen food, causes the water molecules to break loose and travel to the block of ice on the condenser, where their energy is removed by cooling. Pumps then will be needed only to remove the permanent gases.

Heat may be applied to the frozen food by conduction or radiation, or both. Evaporative cooling maintains the ice interface at the necessary subfreezing temperature to keep the product frozen. As the product dries, however, its resistance to heat flow increases, due to the insulating property of the porous matrix of dry material. The thicker the layer of product, the greater is this resistance. The temperature of the heating plate must be kept below the point at which damage to the dried product will occur. Thus the removal of the last 10% of moisture may require as much time as the first 90%.

One answer to this problem would be to use microwave heating to remove the last portions of moisture. One major obstacle to this process is the high cost of generating equipment. There are other problems of shielding, gas ionization and temperature control that make the process rather complicated. Many of these problems may be solved in the near future, and more extended use may be made of microwave heating for at least finishing off the latter part of the drying cycle.

DEHYDROFREEZING

by
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Albany, California

Dehydrofreezing is the process of reducing the weight of a fruit or vegetable piece to about one-half its original weight by warm air drying before freezing. Engineers at the Western Utilization Research and Development Division (L. B. Howard, W. D. Ramage, C. L. Rasmussen, U. S. Pat. No. 2,477,605, Aug. 2, 1949) recommended this method because they had observed that nearly all the irreversible changes occurring in piece dehydration take place only after exceeding 50% weight reduction. Since such a half-dried product would not be sterile, the drying step must be followed by a preservation step -- freezing in Dehydrofreezing, or canning in Dehydrocanning. Besides being lighter, products treated in this way are less bulky because they have undergone considerable shrinkage, most of which is reversed on rehydration. Rehydration is rapid and virtually complete.

Mr. Lazar has visited all of the eight plants in the recently-expanded dehydrofrozen apple industry of Western New York. Operators of these plants have now had one or two seasons of experience in dehydrofreezing and have become familiar with some of the problems likely to be encountered. New dehydrofreezing operations are being planned in other areas, on apples and on other commodities. Academic studies on application of dehydrofreezing to several commodities are also planned or are already under way.

Users of DF apples in commercial baking of pies state that they prefer them over regular frozen apples for several reasons: they more closely resemble the taste of fresh apples, they were easier to use, they were more economical, they kept better when thawed, and they made pies with better texture, flavor, and keeping qualities. Food journals have described the virtues of dehydrofreezing and have predicted that it would have a strong impact on the food processing industry. Consumer acceptance tests have been very favorable.

Although it is 17 years since dehydrofreezing was conceived at the Western Division, it appears at last to "have its foot in the door," and the future looks promising. However, many problems still exist in dehydrofreezing. Development research is still needed for improvement of plant efficiencies and for new and better products. During my recent tours of apple dehydrofreezing plants I observed various degrees of concern, from indifference to seriousness, in the plant operators regarding the improvement of plant practices. Areas where problems exist may be grouped into three main categories: (A) Raw material: variety, maturity, and size of fruit. (B) Processing: piece size and shape, predrying treatment with or without sulfur dioxide, drying equipment used and operating conditions, blanching, packaging, and freezing. (C) Remanufacture: thawing, reconstitution, and additives for intended use, and baking technique.

In general, dehydrofreezers are doing a good job, considering the buyers' limitations on fruit firmness, piece size, and sulfur dioxide content. Experimentation and exploration are not encouraged because of the presently limited market. Development work done in categories A and B above must be matched with corresponding effort in

category C. Research on methods of remanufacture is certainly as important as processing research, if not more so. Education of the baking trade in the use of the new dehydrofrozen products is difficult, but directions and recommended procedures will certainly be helpful to attain this end.

The potential for application of dehydrofreezing appears broad, including apricots, peaches, blueberries, and fruit purees, in addition to apples. Dehydrofrozen vegetables should be a natural, because they might need only the usual boiling required by conventional frozen vegetables before serving. Peas (already successful), carrots, green beans, lima beans, potatoes, sweet potatoes, and squash are good possibilities.

PRESENT STATUS AND OUTLOOK FOR FREEZE DRYING

by
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Freeze drying studies have been conducted for many years by food processors, government laboratories, and equipment manufacturers. The first commercial vacuum contact drier was operated in Norway during the 1946-48 period for drying fish. The British Ministry operated a research establishment and experimental factory for dehydration of foods in Aberdeen, Scotland from 1951 to 1961. Engineers there converted a Danish vacuum-contact drier for freeze drying studies. Their work resulted in publication of considerable data and a much improved technology for dehydrating a broad range of foodstuffs. In the United States around 1940, Earl Flosdorf carried out pioneering investigations at F. J. Stokes Co. The first commercial applications were made here by Armour & Co., Wilson & Co., T. J. Lipton, Inc. and Liana Foods. Numerous installations are now in operation.

The sales volume of freeze-dried foods in the U. S. in 1962 is estimated at $15 million. A list of current producers in the United States, as well as a survey of freeze-drying in other countries of the world, was given. Japan, in particular, is adopting this technique rapidly. Eleven equipment manufacturers in the U. S. now offer equipment for freeze-drying.

Essentially, vacuum-freeze dehydration involves the same processing as does frozen food, plus the added operation of removing water down to a 2% residual moisture under pressures as low as 50-750 microns. Hence, valuable characteristics not found in frozen foods are necessary to justify added expense of costly drying process.

The operation proceeds through a sublimation stage, during which ice is vaporized directly by means of heat radiated from plates, between which trays carrying frozen particles are positioned equi-distantly. Rapid evaporation cools the surfaces sufficiently to keep the particle temperature below the safe limit of 140°F., despite platen temperatures of 300°F. or higher. Maintenance of chamber pressures low enough to keep the ice interface about 2°F. below its eutectic point is imperative during this stage.

Subsequent drying to low final moisture (approximately 2%) following sublimation of all ice proceeds slowly. Platen temperatures must fall to 170°F. if heat damage is to be avoided. Automatic regulation of temperature and pressure for optimum drying rate is becoming routine. New chamber designs include fixed spacing of trays between radiating heating surfaces, with automation of materials handling. Choice of vacuum and vapor removal systems is determined by local conditions.

Commercial production has been stimulated by military contracts, mainly for freeze-dried meats. Armour, Wilson, General Foods and United Fruit & Food are offering a variety of meat, fish, poultry, vegetable and fruit items for general sale. Lipton and Campbell Soup freeze-dry special components for their own soup mixes. Instant coffee is judged the equal of brewed coffee when Maxwell House utilizes its vacuum chambers for dehydration. At least four contract freeze-dehydrators are now operating on a variety of products.

Foods are freshly frozen before lyophilization and retain their original freshness, color, flavor and shape during the drying operation. Their long shelf life at room temperature, when adequately protected against moisture and, in many cases, oxygen uptake, as well as their generally rapid rehydration rate are a real asset for freeze-dried foods. They are particularly useful as components in food specialties where their higher cost has only a minor effect on the selling price. Expansion of military use in "quick-serve" meals would quickly absorb total production of all commercial facilities in the U. S.

Institutional sales volume will undoubtedly precede widespread retail marketing. Certain items, such as asparagus tips, find a ready export demand. Light weight, long storage life and ease of preparation make freeze-dried foods a natural for certain uses, such as camping and prospecting. Considerable housewife education will be needed to insure success in home use.

Freeze-drying equipment is costly in relation to capacity. The process is slow and operation requires a high degree of technical skill. Packaging of dry product is expensive. Application is apt to be limited to items which are intially expensive, such as mushrooms, or which cannot be dried satisfactorily by cheaper methods, as with asparagus or meats. Operating costs vary widely, but in a plant that has a capacity of 50 tons of raw material in 24 hours and that operates 300 days annually on an eight-hour turnaround cycle, costs as low as 3¢ per pound of water removed should be realizable.

Tin makes the best package, although laminated flexible pouches are cheaper. Continuous search for cheaper, effective containers is essential. Great acceleration in production of freeze-dried foods at lower cost has occurred in the past three years. A common prediction is that annual volume in the U. S. of one billion pounds will be attained by 1970. Vacuum freeze-drying will find its place in the food preservation picture, but will always be much lower in volume than canning or freezing.

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